APR 26 1929

Volume 15 March, 1929 *Number 3*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Factors
Which May Affect
Power Development
in the
Automotive Engine

PUBLISHED MONTHLY BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

"Let us be frank about this!"

IN the operation of the automotive engine, power development is of prime importance. The motorist recognizes this; but often his knowledge of the factors which affect power development is limited.

Such superficial knowledge will often lead to improper conclusions regarding the cause of trouble, and dissatisfaction, generally.

Today, when the engine knocks, the gasoline will be blamed; tomorrow the condition of the bearings, or "carbon."

It is easy to understand how motorists in this frame of mind can become prey for any unscrupulous repair shop mechanic who may want a new excuse for overhaul.

The accompanying article takes up in detail the factors which affect power development in the automotive engine. Once understood, they will lead to a more intelligent operation of the automotive vehicle, a fair-minded attitude toward the industries involved, and a decrease in expense for repair or overhaul.

THE TEXAS COMPANY

Texaco Petroleum Products

DEPT. H, 17 BATTERY PLACE, NEW YORK CITY

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A Technical Publication Devoted to the Selection and Use of Lubricants

Published Monthly by

The Texas Company, 17 Battery Place, New York City

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Vol. XV March, 1929 No. 3

Change of Address: In reporting change of address kindly give both old and new addresses.

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Factors Which May Affect Power Development in the Automotive Engine

THE development of maximum power from an automotive engine, regardless of the type of service involved, requires an intimate knowledge of constructional features, operating conditions and the requisite characteristics of the fuel and lubricating oil.

From a constructional viewpoint power development may be reduced by:

> Piston rings functioning improperly, faulty bearing construction, or ineffective means of lubrication.

Likewise, in operation the performance of the average automobile, bus, truck or tractor engine will be impaired by:

> Faulty carburetion, excessive choking, abnormal idling or overloading of the engine.

All the above, however, are more or less dependent upon the ability of the gasoline and motor oil to counteract their potential detriments.

In the case of gasoline we must, therefore, be interested in noting:

> How the distillation range will indicate the volatility, the degree to which sulfur may prove damaging to the engine, and to what extent the gravity should be considered in selecting such a fuel.

In turn, the selection of a motor oil will require knowledge of the:

> Viscosity,
> Pour test and,
> Carbon residue content.

Constructional Requirements

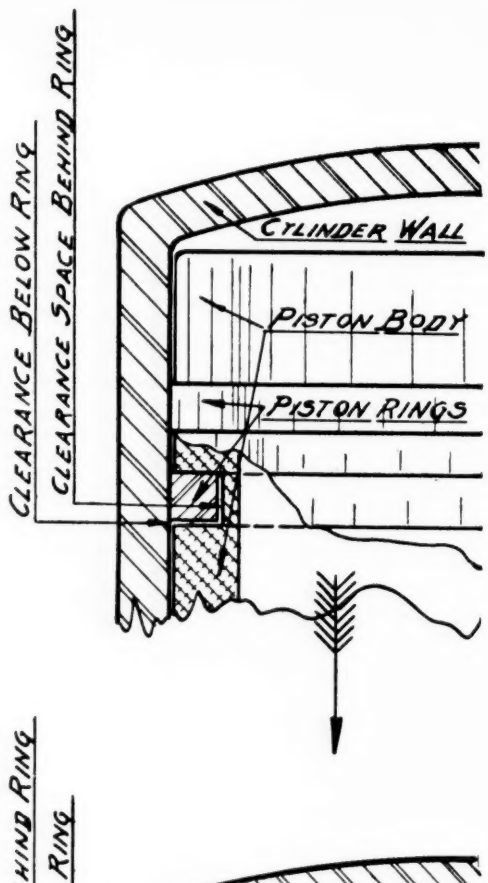
PISTON RINGS

The function of the piston rings is to enable flexible following of the cylinder bore by the piston at all speeds, and under varying temperatures, so as to insure a seal between the piston and the wall of the cylinder. As a result, piston rings must work freely in their respective grooves, in order to provide the necessary seal, and prevent the motor oil from seeping under and back of the rings.

The reciprocating movement of the pistons in the cylinders and the manner in which the piston rings follow the cylinder bore under varying temperatures, determine to a great degree the efficiency of the engine. The cylinder bore must, therefore, be smooth and absolutely concentric, otherwise the piston rings may tend to vibrate.

Accurate Fit Essential

While a close fit is necessary between all piston rings and the respective piston grooves,



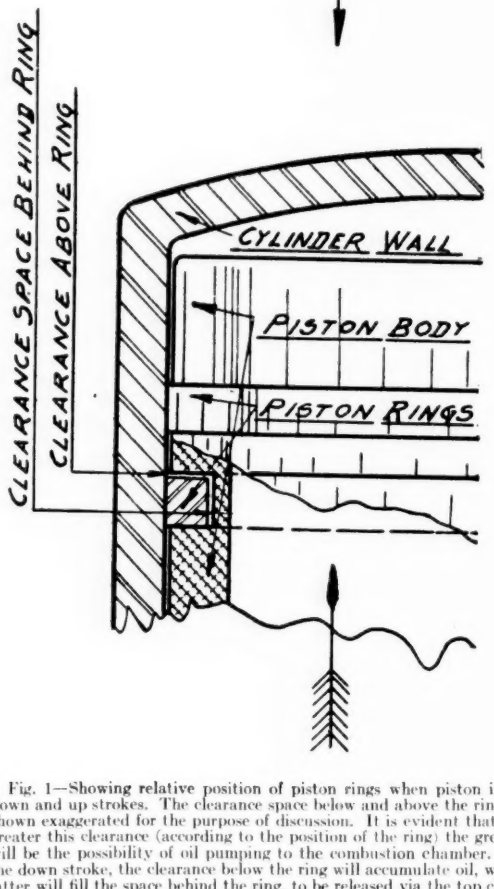


Fig. 1—Showing relative position of piston rings when piston is on down and up strokes. The clearance space below and above the rings is shown exaggerated for the purpose of discussion. It is evident that the greater this clearance (according to the position of the ring) the greater will be the possibility of oil pumping to the combustion chamber. On the down stroke, the clearance below the ring will accumulate oil, which latter will fill the space behind the ring, to be released via the top clearance on the up stroke when the ring reverses its position with respect to the sides of the groove.

it is important that rings shall not bind under any operating condition, otherwise their value as a sealing medium will be lost. Furthermore, should binding occur vibrations may develop.

The diagonal or stepped opening of any piston ring must be sufficient to permit the expansion of the ring when exposed to high temperatures, and yet it must be as small as possible to prevent the passage of motor oil or gasoline vapors. Here again the cylinder bore must be absolutely concentric, otherwise it is quite impossible to get efficient operation, no matter what the type of ring, or the care with which it has been fitted into the piston.

There must, furthermore, be an accurate fit between the cylinder bore and piston, with the minimum clearance practicable. Normally the skirt should have a clearance of about .002 of an inch, while the head, which is usually set back because of its greater expansion, should have about .010 of an inch.

The practice of laying pistons down on a work bench either when assembling the engine or overhauling it may often cause them to become out-of-round, with the result that they may tend to scuff and ultimately "slap" when subsequently put into service.

Grade of Oil a Factor

If, however, we are to expect piston rings to expand and contract radially, as intended, in the piston ring grooves, it is essential that a high grade motor oil be employed, which leaves a minimum amount of carbon residue; otherwise carbon will collect behind the rings to cause them to become set.

Where this occurs a piston ring will be converted into a reamer, to soon cut the polished surfaces of the cylinder bore and permit an excessive amount of oil to reach the combustion chamber. There will also be the possibility of passage of the expanding fuel into the crankcase, to cause sludging and dilution of the motor oil.

DESIGN AND ADJUSTMENT OF ENGINE BEARINGS

Bearings have occupied a position of prominence in modern automotive engine design. In this connection, much attention has been given to the relative merits of oil groove location, as well as the importance of properly fitting bearings, in order to insure continued and effective lubrication.

Clearance Must be Adequate

Although it has long been recognized that such bearings should have sufficient clearance to permit ready circulation of the motor oil, it is still frequent practice when overhauling

engines, to take up on the connecting rod caps and main bearings so tightly that a film of oil cannot penetrate between the contact surfaces of the rotating elements. The ultimate result of such a condition will be heat generation with subsequently a burned out bearing.

In general, it can be stated that an engine bearing will be destroyed only because of two direct reasons, viz.:

The lack of oil, or
Hammering out of the bearing where a connecting rod or main bearing cap has become loose.

By lack of oil is meant failure of oil to reach the two surfaces to be lubricated, or resist the pressure. This applies to engines where oil supply has been completely consumed, as well as to cases where a full supply of oil is carried, but for some reason it does not reach the wearing surfaces.

This latter may be caused by an oil pump being out of order, a clogged strainer or oil bleed, or the fact that the bearings have been fitted so tightly that oil cannot penetrate between the bearing surface and the journal. In any case, it is lack of oil.

MEANS OF LUBRICATION IMPORTANT

In accordance with the theory and practice of lubrication it has been developed that an adequate film of oil between any two surfaces to be lubricated, will effectively prevent wear of the respective moving parts provided that film is continuously maintained during operation.

The means of lubrication is of course important in this regard. If positive circulation of an adequate volume of oil is practicable, and if the oil has been carefully selected as to properties which will render it capable of functioning under the prevailing operating conditions, there should be no geographical relationship between the source of the crude from which this oil has been refined and the amount of wear which may result in the normal operation of an internal combustion engine.

Where it is impossible to maintain a suitable film of oil due to ineffective means of lubrication, or road dust or other foreign matter gaining entry into the engine and becoming absorbed by the lubricating oil, wear will result between the rotating or reciprocating parts regardless of the original purity, source or characteristics of this oil.

Research has indicated that the presence of abrasives such as road dirt, etc., is responsible for the majority of all engine wear. Other causes, such as metal fatigue or vibration, are relatively minor.

Oil filters and the filtering of the air passing through the carburetor have, however, done and will do much toward reducing engine wear, for they insure maintenance of the motor oil in as nearly a state of purity as possible, provided its original refinement has been such as to insure the least amount of carbon deposit on the piston heads or valves, and adequate fluidity and circulation.

Carburetion

Effective and positive carburetion may be regarded as the salient factor in the operation of the automotive engine, and the development of maximum power per gallon of gasoline consumed. In turn, however, carburetion will be affected by carburetor adjustment, uniformity of the fuel charge, valve adjustment, compression ratio and the means of ignition. Very frequently faulty design or adjustment of certain of the elements involved may be the cause of knocking which is erroneously attributed to the fuel.

Carburetor Adjustment

As a rule, there are many carburetors which will be improperly adjusted. Where this prevails, it will be impossible to get the greatest efficiency from the engines involved.

Faulty adjustment may be due to poor construction, to wear which may lead to air leaks, to parts having become enlarged, or to springs or other controls so badly thrown out of adjustment that the originally desired carburetor setting is lost.

As a result, carburetors should be given attention from time to time to make sure that all adjustments or controls are in good order.

Carburetion is of equal importance along with choking or idling of the engine, for it will affect the richness of the fuel mixture, and the extent to which dilution of the motor oil may occur, to result in the latter suffering a loss in lubricating ability.

THE PRINCIPLES OF ENGINE OPERATION

There is an ever increasing public demand for more powerful and smoother running engines of maximum flexibility and quietness. And yet, with all this interest, the phenomenon of combustion is entirely too vague to many, despite the attention given by technical journals and the engineering societies. In conse-

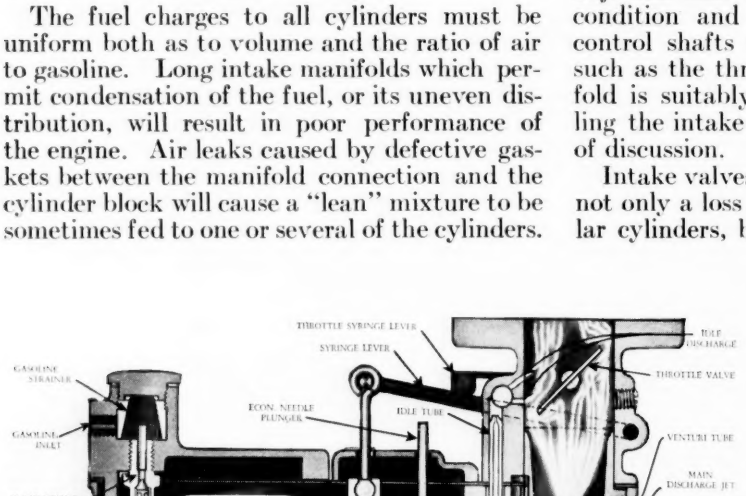
quence, the question of "engine knock" is but little understood. To show the relation which this may have to carburetion, a superficial study of the theory of the Otto cycle internal combustion engine, as well as the principles of fueling will be advisable.

To attain efficient engine operation, the first thing to be considered is the delivery of well balanced and proportioned charges of fuel to combustion chambers of uniformly smooth and clean interiors, having uniform compression at all engine speeds.

In operation an internal combustion engine draws a charge of fuel into the combustion chamber as a result of the partial vacuum created by the downward movement of the piston. This fuel charge consists of approximately thirteen parts of air into which is atomized one part of gasoline metered by the carburetor through which it passes.

Uniform Fuel Charge Essential

The fuel charges to all cylinders must be uniform both as to volume and the ratio of air to gasoline. Long intake manifolds which permit condensation of the fuel, or its uneven distribution, will result in poor performance of the engine. Air leaks caused by defective gaskets between the manifold connection and the cylinder block will cause a "lean" mixture to be sometimes fed to one or several of the cylinders.



Courtesy of Stromberg Motor Devices, Inc.

Fig. 2—Working view of the Stromberg Syringe vis-a-gas carburetor.

Irregular fuel charges delivered to the cylinders when compressed prior to being ignited vary in the pressures obtained on the power stroke, and the result is that all the cylinders do not develop like power. A difference in power developed in the respective cylinders causes the engine to be dynamically unbalanced and accompanied by vibrations which may be very often noticeably audible.

Sometimes the fuel charges, while uniform at normal running speeds, will vary at critical engine speeds, such as at a moment of rapid acceleration or deceleration. In this regard, if we consider the two standard firing orders for six cylinder design: 1-5-3-6-2-4 or 1-4-2-6-3-5 we will see that after the piston of number one cylinder has started down on an intake stroke and the crankshaft has travelled through one-third of a revolution, that number five or number four commences to draw in a charge of fuel. If non-uniform fuel charges are involved, this may set up a disturbance in the intake manifold and often is responsible for unbalanced vibrations being set up in the engine.

Intake Valve Adjustment Important

Assuming that the carburetor is properly adjusted and that it is in good mechanical condition and free from leaks around such control shafts which may extend through it, such as the throttle shaft, and that the manifold is suitably designed, the valves controlling the intake ports should be the next point of discussion.

Intake valves that do not seat well will cause not only a loss of compression in their particular cylinders, but also will disturb the proper distribution of the fuel charges to the other cylinders. Allowance must be made for valve stem elongation due to expansion when hot, otherwise the lack of sufficient clearance between the valve stem and the push rod will result in the valve "riding" and the intake port will not be sealed.

On the other hand, too great a clearance will prevent a full charge of fuel from entering the combustion chamber, for if there is too great a clearance the push rod will be unable to raise the valve to its extreme position of lift and the result would be the same as throttling the charge to that cylinder.

Valve timing and the condition of the valve faces, seats and guides must also be considered. The action of valves as to their freedom to close with the least amount of lag is very important. Noisy or audible vibration of the springs will often be an indication of faulty operation. This may interfere with the uniformity of the

fuel charges to the cylinders especially where the bushings of certain valve guides have become worn to such an extent as to permit air leaks around the respective valve stems and into the intake valve chamber.

Exhaust Valves Must Withstand Heat

The exhaust valves of an engine need particular attention because of the terrific heat to which they are exposed during the exhaust strokes. If they warp or are damaged, to in any way prevent a tight seal of the exhaust ports during the compression and power strokes, the result will be uneven power impulses due to non-uniform compression of the fuel charges and an attending series of vibrations ranging from those that are inaudible to those that result in a distinct "knock."

THE PRINCIPLES OF IGNITION

The ignition of the fuel charge is accomplished by an electric spark being brought into contact with the compressed fuel in the combustion chamber by means of the spark plug.

It has long been recognized by builders of spark plugs that if the insulator can be kept at a relatively high temperature, the possibility of fouling from oil vapors or heavy ends of gasoline will be greatly reduced.

During the years of experimentation, we must bear in mind that the usual position of the spark plug was over the intake valve; therefore, the electrodes were naturally cooled by the flow of cool gases entering the combustion chamber on each intake stroke.

Effect of Compression Ratio

With a demand for increased power and more flexible engines, however, the compression ratio of the automotive engine has been markedly increased. This involves compressing the fuel more fully on the compression stroke; reducing the size of the combustion chamber; and placing the spark plugs in the dome of the head and away from the cooling influence of the fresh charges of fuel.

In consequence, spark plug operating temperatures are today more nearly at a point where the heated electrodes may cause highly volatile fuels to ignite prematurely.

Pre-ignition of the fuel is also very often caused by particles of carbon, or projections such as wall scale, becoming incandescent.

Spark Controls

It is almost general practice today to employ a combination of both manual and automatic spark control. The manual range is from a fully retarded position at top dead center to a position twenty degrees before top dead center; the automatic range, controlled by a governor built into the ignition unit, giving an additional twenty to twenty-five degrees advance; a total advance before top dead center of forty-five degrees.

Unfortunately, it very often happens that the automatic advance mechanism becomes jammed and instead of retarding the timing of the spark, it holds this latter at the maximum advance position, resulting in the ignition of the charge of fuel at too early a position with relation to the speed of the piston travel. This may result in a "knock" or "ping" being heard.

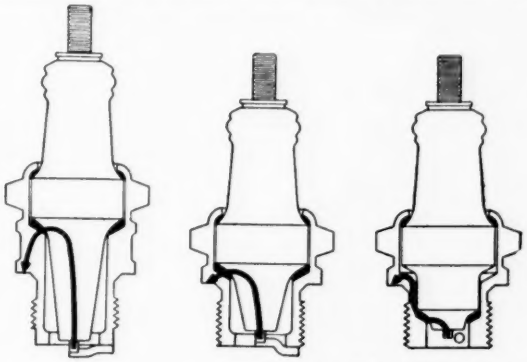
In such a case, even though the operator may retard the manual control, the jammed automatic will hold the timing twenty-five degrees advanced, thus the purpose of timing is defeated.

Relation of Timing to Compression Ratio

The timing of the ignition spark is dependent on several contingent elements of the ignition system. We will consider the usual coil and battery system. In general, the greater the compression ratio, the greater must be the spark voltage to overcome the resistance between the electrodes of the spark plug. The use of induction coils adapted to low compression service will seldom suffice, if maximum efficiency is to be attained.

Function of the Battery

With a three-cell battery we have a potential of 6.6 volts which is used to maintain the magnetic field of the induction coil by establishing



Courtesy of AC Spark Plug Company.

Fig. 3—Showing the path of heat flow in spark plugs of different resistance. Note that heat flows outward and through the seat, in a direction commensurate with the resistance offered. Design should be such as to always insure retention of sufficient heat to prevent possible fouling which might cause loss of power.

a circuit through the primary circuit. At the predetermined moment that a spark is required at the spark plug, this circuit is broken by the interrupter.

A condenser parallel to the interrupter points sets up an alternating current through this

same circuit so that the magnetic field is instantly neutralized. A secondary winding in the induction coil, because of its position in the magnetic field, is subjected to this magnetic disturbance with a result that in its circuit a secondary current of high voltage is induced.

It is important to remember that the slightest variance in the lift of the interrupter points, or any sluggishness of the condenser or ignition coil, or wear in the distributor may cause erratic and irregular performance of the engine.

Determining the Cause of "Knocking"

As a result, when trouble is reported as being due to fuel detonation, as indicated by "knocking," the first thing to determine is what is the mechanical condition of the engine, viz.:

Is pre-ignition being developed due to heavy carbon formation as a result of using carbon forming motor oil, or is it due to an overheated spark plug, or faulty valves?

Is the carburetor adjusted too lean?

Does the ignition mechanism function properly?

Does the vacuum tank, wind shield wiper or any other accessory allow too much air to enter the intake manifold at certain speeds and destroy the balance of the fuel charges?

Fuel Requirements

DISTILLATION A FACTOR IN EVALUATING GASOLINE

In a discussion of the pros and cons as to what constitutes a good gasoline, considerable attention is today devoted to the distillation range. As a result, it will be of interest to understand just what this means, and the bearing which it may have upon effective carburetion. The principle involves the vaporization of liquid gasoline, when it passes through a carburetor.

The extent to which this will occur and the rate of gasification will vary directly as the temperature of the air into which this gasoline is injected.

In actual practice this will mean that on a cold day the amount of liquid gasoline which may pass to the engine will be greater in proportion to the amount of gas developed.

If we actually squirted this gasoline stream into the air we would find that it would not all evaporate immediately, but that there would be a lot of small drops or fog produced.

If, however, the temperature is raised, a point will be reached where this gasoline will pass very rapidly into the gaseous state.

In the carburetor, of course, there is but a small fraction of a second involved from the time the gasoline leaves the jet until it gets into the cylinders of the engine. As a result, rapid vaporization is most desirable.

In this connection, it is well to state that the lighter or more volatile a petroleum product, the more readily will it pass into the gaseous state. As a result, it is natural for lighter naphthas to react in this manner more rapidly than heavier distillation products, such as kerosene. These latter, in fact, will vaporize very slowly, if at all, at ordinary temperatures. However, kerosene in particular, will pass over to the gaseous state if subjected to sufficient temperature.

Method of Test

Gasoline is evaluated by means of the distillation test. This comprises heating of a measured sample in a flask at atmospheric pressure. When a temperature of about 100 degrees Fahr. is reached above the liquid (not in the liquid), vaporization commences.

The temperature at which the first condensable vapors are produced is called the "initial point." The temperature is then gradually raised to result in more and more gasoline passing off as vapor, until a vapor temperature of somewhere around 400 degrees Fahr. is reached, when, with the best gasolines, all will have been distilled over except possibly a fraction of one per cent. This temperature is called the "end point."

During this process of distillation, temperatures are usually taken at which specific percentages have distilled over; the petroleum industry generally standardizing on twenty and fifty per cent.

Average Distillation Temperature Important

The carburetor technologist, in considering the action of his carburetor, looks at another point than the "initial," "twenty," "fifty" and "end point," and that is the average distillation range. In actual carburetor operation, it has been found that the gasoline may not vaporize in strictly the same manner as it does from a distillation flask, because vaporization from the carburetor takes place in the presence of an excess of air, and the gasoline will go into the gaseous state at a much lower temperature than is exhibited with a standard distillation flask.

A good example of this phenomenon can be

cited in the case of water. Here vaporization in a flask will not occur until a temperature of 212 degrees Fahr. is reached, yet water will vaporize perfectly in a current of air at a much lower temperature. So the temperature of a carburetor does not have to be 400 degrees Fahr. in order to obtain complete gasification of the fuel.

Heat Supplied in Part by the Air

On the other hand, any liquid, when it goes into the gaseous state, requires heat. This latter cannot be applied by a flame, as is customary in laboratory distillation testing; therefore, it must be absorbed from the air into which the gasoline is vaporized; that is, when the gasoline goes through the carburetor jet, it cools the incoming air. This, however, will in turn lower the tendency of the gasoline to go into the gaseous state. A good example of this is the cooling effect that water has when it vaporizes from your hand in a current of air.

As a result, we have two factors more or less balancing each other, viz.: the lowering of the temperature of the air which tends to decrease the rate of vaporization, and the excess volume of air which tends to increase it. In actual operation, it has been developed that the latter has a greater effect than the former, so complete vaporization or gasification of the fuel is attained at temperatures considerably below 400 degrees Fahr.

In addition to the above, however, inductive systems will frequently provide for application of heat to the vaporized mixture of air and fuel before it enters the cylinders, and furthermore, after such entry we must remember that there is quite a volume of hot burned gases available with which the air-vapor combination mixes in the cylinder, which in turn will also tend to drive any remaining liquid gasoline over into the gaseous state. The more thoroughly this can be accomplished before the fuel charge enters the cylinder, the less pre-heating will be required to bring about complete combustion. It is for this reason that a highly volatile gasoline will give quicker response on starting and on acceleration in cold weather.

When starting, it must be borne in mind that there is no hot spot available to serve as a preheater for the gasoline vapor, and frequently when rapid acceleration is required there will be a sudden call for fuel mixture, which may not always have time to become properly heated by the hot spot before it is called upon to do work. A gasoline which has a good average distillation value will function best in developing easy starting and acceleration.

From the above it would, therefore, seem that the lighter the gasoline or the more easily it will vaporize, the better the product, but we must remember that after the car has been run a while everything has been thoroughly heated up, and if the gasoline vaporizes too easily before it gets to the jet in the carburetor it may cause unequal operation.

As a result, it is essential that vaporization shall not commence at too low a temperature. This brings up another point of interest, especially where we are too prone to look at a distillation curve with 100 degrees Fahr. initial as indicating that the gasoline will start to vaporize at 100 degrees Fahr. As a matter of fact, 100 degrees Fahr. is the temperature in the vapor phase above the liquid, and the liquid itself may be 40 or 50 degrees higher before boiling takes place.

Effect of the "End Point"

In the above discussion but little has been said about the "end point." This naturally has an effect on the average distillation temperature of the fuel, but also it may have an effect on the amount of heavy ends or less volatile fractions that are retained by the lubricating oil on the cylinder walls.

There is considerable discussion as to how these heavy ends get into the lubricating oil; some authorities claim that they comprise ungasified gasoline that is drawn into the cylinder, and subsequently thrown into contact with the lubricating film by turbulence. Others have developed that even gasified fuel, when sweeping across a lubricating film, will be absorbed to a certain extent.

Regardless of the mechanism, the fact remains that it does get into the lubricating oil, and will not leave it unless the temperature in the crankcase is raised well over 175 degrees Fahr. Furthermore, it is fairly well proved that the greater the average temperature of the upper distillation range, the greater the crankcase dilution. As a result, the better the vaporization before the fuel-air mixture reaches the intake manifold, the better and more even will be the distribution of mixtures, the lower the rate of crankcase dilution and the more dependable the degree of lubrication.

Reference has been made elsewhere in regard to the matter of Baume gravity and the extent to which this should be considered by the motorist or consumer in buying gasoline. It is evident, however, from the above remarks in connection with distillation and the facts brought out in connection with Baume gravity, that this matter of distillation should be given prior consideration in determining the actual value of gasoline as an automotive fuel.

SULFUR

An extremely important factor to consider, both in the manufacture and usage of automotive fuels, is the element sulfur. As petroleum crude oils are received in the refinery they may or may not carry a comparatively high sulfur content. This will all depend on their source.

The sulfur content of crude oils will vary widely. Where relatively high, the subsequent sulfur content in any gasoline derived therefrom will usually be proportionately high.

In the process of refining a certain amount of sulfur compounds are included in the finished gasoline.

The extent to which such sulfur contamination may exist is determined by what is known as the corrosion test, or by the "doctor" test. This latter, however, is more or less subsidiary to the corrosion test, which is today taken as the final indication of corrosive sulfur content in a gasoline.

The Corrosion Test

This test, which should be performed on every finished gasoline before it is put on the market, according to the American Society for Testing Materials—"Shall be used for the detection of free sulfur and corrosive compounds in gasoline.

The procedure as recommended by the A. S. T. M. is as follows:

"1. A clean strip of mechanically polished pure sheet copper about one-half inch in width and three inches in length shall be placed in a suitable clean tube or sample bottle. Gasoline under test shall be added so that the copper strip is completely immersed. The test tube or sample bottle shall be closed with a loosely fitting cork and held in a suitable bath at 122 degrees Fahr. (50 degrees C.).

At the end of three hours the gasoline exposed strip shall be removed and shall be compared with a similar strip of freshly polished copper.

Detection of Sulfur

2. The presence of sulfur or corrosive sulfur compounds is indicated by the corrosion or discoloration of the gasoline exposed strip when compared with the fresh copper strip.

3. (a) Gasoline shall be reported as passing the test when on examination the exposed strip shows not more than extremely slight discoloration as compared with the fresh copper strip.

4. (b) Gasoline shall be reported as not passing the test when on examination the exposed strip shows more than extremely slight discoloration as compared with the fresh copper strip."

The "Doctor" Test

The "doctor" test embodies agitation of a certain volume of gasoline with a caustic soda solution of litharge. A so-called "sweet" gasoline should show no reaction when so treated.

If, however, there is any free sulfur present in any of its various forms, the "doctor" test will develop more or less of a black precipitate, and the gasoline sample will show discoloration. The odor of hydrogen sulfide may also be evident in such a gasoline when heated. In the petroleum industry, the usual term for a gasoline which reacts with the "doctor" solution is "sour."

It requires but a very slight percentage of sulfur to render a gasoline "sour" and to make it questionable as a fully satisfactory fuel for the automotive engine.

Operating Conditions Must be Considered

From this latter viewpoint, however, the operating conditions to which it may be subjected must be taken into account. If, for example, comparatively continuous operation prevails, as in the case of motor transport equipment, the maintenance of the engine in heated condition will preclude development of condensation to any appreciable extent. As a result, the possibility of moisture and subsequent reaction of this latter with the sulfur in the gasoline will be minimized.

In a high grade straight distilled gasoline, 0.10 per cent of sulfur may be regarded as the dividing line. In other words, below this figure the detrimental results will be virtually negligible. On the other hand, with certain blended gasolines it may be necessary to operate with a sulfur content frequently as high as 0.20 to 0.30 per cent. This will be especially true where benzol is used in compound for the purpose of improving anti-knock qualities in the resultant gasoline.

Sulfur as a constituent of straight distilled gasoline, or of benzol will normally be present as a more or less complex compound of the other chemical elements involved. Rarely will it occur as essentially free sulfur.

The Reactions Involved

The process of combustion, however, will have the same effect in either case. Oxidation will bring about the formation of sulfur dioxide (SO_2). This latter is a gas of highly reactive tendencies, especially in the presence of water vapor. In view of the amount of water vapor

which is developed during combustion, its ultimate reaction with sulfur dioxide to form sulfurous acid (H_2SO_3) is a normal consequence.

In other words, we have the genesis of corrosion, for while sulfurous acid is comparatively weak, it is also unstable from the viewpoint of oxidation, i. e., it can be ultimately expected to take up one more atom of oxygen to bring about the formation of sulfuric acid, a far more highly corrosive product. Oxidation of sulfurous acid is hastened of course, by heat, and in the presence of air and metallic particles.

During engine operation, where blended gasolines, or straight run fuels from uncertain sources are used, corrosion from sulfuric acid may be a highly potential possibility. The extent to which engine bearings and other wearing elements may be damaged will, of course, depend on how continuously such fuels are used, and the degree of seal which is being maintained by the piston rings.

Low Temperatures Conducive to Corrosion

Research has developed that corrosion due to sulfur reactions will probably occur more readily in cold weather, due especially to the greater possibility of abnormal condensation of water vapor developed in the process of combustion. It is logical to presume, therefore, that effective means for reduction of condensation will reduce the possibility of active chemical reaction with sulfur.

This can be brought about by preventing cooling down of the engine to an abnormal degree, especially during intermittent operation. Suitable radiator covering, installation of shutters, the use of a thermostat in the cooling system, and means to insure proper crankcase ventilation are all regarded as of marked advantage in this regard, especially if used in combination with one another.

HOW WATER MAY AFFECT OPERATION

Water in the crankcase or oil pump of an automotive engine will be conducive to rust, ice, emulsification and sludge formation. This will be especially true in cold weather or where road dust, dirt, carbon or metallic particles have been allowed to accumulate to any extent.

The oil filter and air filter have already been spoken of as factors in this regard. But above all, and especially in cars not equipped with these accessories, it is important to remember that periodic changing of oil and careful flushing of the crankcase and lubricating system will be most advisable in the interests of prolonging the life of bearings and piston rings, the prevention of undue wear on cylinder walls, and the assurance of more dependable operation.

Why Water Is Present

Just how water may gain entry into such a carefully built and enclosed machine as an automotive engine will be of interest. The possibility of entry from an external source is remote, provided reputable gasoline and motor oil are used which can be depended upon to be water-free. Far more frequently will it be developed within the engine itself, as a product of combustion or condensation.

As a Product of Combustion

The extent to which water may be developed in the process of combustion can be realized by holding a glass receptacle over the end of the exhaust. The exhaust as it passes to the air is usually gaseous in form, though a certain amount of saturation may occur through partial condensation in the muffler.

In gaseous form water cannot be as readily observed; hence the idea of using a glass to serve as a crude condenser. After a few minutes of this collection of the exhaust, drops of water can be actually noted on the walls of the container. The colder the latter the more rapidly will condensation occur.

This is exactly what takes place within the engine also, but, of course, to a far less degree, for the majority of the exhaust is naturally carried to the air via the muffler except in an engine where the piston seal is poor. At all events, however, some of this exhaust with its vaporous water content may pass to the crankcase, and the cooler the latter the more readily will subsequent condensation occur.

Condition of Engine a Factor

The degree to which such water may find its way into the lubricating system will depend upon the condition of the engine. In other words, where piston rings are worn or cylinder walls scored or abraded to result in abnormal clearance, an effective seal cannot be as readily maintained by the lubricating oil as in an engine where the proper clearance exists between the pistons and cylinder walls.

High clearances will be conducive to leakage. This may involve loss of compression due to blow-by or leaking of combustible fuel vapor on the explosion stroke; as well as the possibility of water leakage past the piston rings and into the crankcase.

In cold weather, and especially on starting, water-contamination of the lubricating oil may increase very rapidly. This is another reason why motor oils should be changed more frequently in winter than in summer.

It is the opinion of authorities that virtually as much water vapor is developed in the process of combustion as there is fuel consumed. How much of this will ultimately reach the

crankcase to mix with the oil therein as actual water will, of course, depend on how effectively the piston rings and lubricating film function in the maintenance of a suitable seal. It would be unwise to attempt to give a figure in pints of water for example, per gallon of gasoline, or per hour of operation; there are too many variables involved as already stated.

Condensation Also a Source

Water, of course, may also be condensed from the air within the crankcase, for under normal conditions of design air has full access through the crankcase breather.

Here again the variables involved will preclude even an approximate estimate of how much water to ultimately expect. It will depend upon the moisture content of the air, the weather, the altitude, the atmospheric temperature, the frequency of starting and stopping and the extent to which the engine actually becomes properly heated.

Condensation from excessively moist air may, of course, also occur within the gasoline tank, especially where the amount of air in the tank is high and where the car is stored in a warm garage and then driven out under comparatively low atmospheric temperatures. This factor must be considered even where the highest grades of gasoline are used.

Under widely varying temperatures condensation and development of water in the gas tank will be most prevalent, and in winter more so than in summer.

Water in the Gasoline

The presence of water in gasoline should be carefully guarded against in cold weather operation, due to the possibility of its giving trouble by freezing in the gasoline pipe, carburetor, or even the bottom of the storage tank. Should a drop of water come in contact with the fine mesh strainer located in the fuel line it may entirely cover the mesh with a film. Freezing of this film, which might happen even when immersed in the fuel, would cause a stoppage in the flow of gasoline, perhaps even to the extent of shutting off the entire supply.

To locate the source of such trouble while out on the road might be a difficult matter, as the frozen film covering the screen may not be readily apparent to the eye, and considerable labor and time would no doubt be involved before the cause of the stoppage in the fuel line could be ascertained. Even if such a film of water did not freeze there would still be the possible objectionable feature of misfiring.

Water Indicated by Misfiring

Water in the carburetor is indicated by misfiring. In this event the carburetor drain should be opened to remove any slugs of water that may be present. It would also be advisable for the motorist to thoroughly inspect his tank for the presence of water at the earliest opportunity, and to drain the gasoline from the system and strain it.

Separation of Water

Unless a device specifically designed for removal of water from the oil in service is installed, emulsification and sludge formation can be the normal expectation. But these developments will, of course, not occur as rapidly with new or comparatively fresh oil as later on when the oil has been in service for perhaps several hundred miles.

In other words, the extent to which water will be held in suspension will depend upon the degree of contamination of the oil from other sources. The greater the purity the more readily will emulsions be dissipated and water precipitated to the bottom of the crankcase or oil pump. Draining off of perhaps a pint from this latter every hundred miles when the engine is cold and adequate precipitation has occurred, should be a factor in keeping down water and foreign matter accumulation and the development of serious sludging. It is not a difficult procedure and is certainly worth the time and trouble required, especially where a comparatively costly engine is involved or where continued service is desired with maximum reduction in time lost or upkeep expense.

The Cause of Rust in a Cold Engine

In view of the fact that under average operation the occurrence of condensation, the retention of a certain amount of water in the engine, and its ultimate presence on the cylinder walls and in the crankcase oil will be prevalent, rust formation, where such an engine is allowed to stand for any length of time will frequently occur.

Research has indicated, however, that if provision is made to maintain the temperature of the engine cooling water sufficiently high (i. e., in the neighborhood of 180 degrees Fahr.) this possibility of rusting will be decidedly reduced. In effect this amounts to using means to prevent the engine and crankcase from cooling down too rapidly when standing. This can be partially accomplished by covering of the radiator, and storage in a warm garage.

Another effective means of reducing the possibility of rust formation and water accumulation, especially on cylinder walls, is to provide for adequate means of serving the cylinders with an abundant supply of oil on starting.

GRAVITY

The extent to which gravity should be considered as being indicative of the value of any

gasoline as fuel for the automotive engine is frequently over-emphasized by many consumers. An important point to remember in this regard is that the ultimate gravity of any particular grade of gasoline will depend upon the type of crude from which it has been produced, and the extent to which it has been "cracked." As a general rule, if a paraffine base crude is used the resultant gasoline will show a somewhat higher Baume gravity than a gasoline of equal or similar refinement (same distillation range) produced from a naphthene base crude.

It is obvious, therefore, that adequate knowledge of the source and manner of distillation is essential prior to placing any value upon the indicated Baume gravity of any gasoline in question.

Motor Oil Characteristics

VISCOSITY

The viscosity or body of an oil, as it is more generally understood by the average motorist is of considerable importance, especially under warm weather and intensive driving conditions. It has a decided effect upon oil consumption.

To realize this it is essential to appreciate that the act of lubrication requires the development and maintenance of a suitable film of lubricant on the cylinder walls and all bearings—*at the temperatures of operation.*

Normally these latter will not exceed 300 degrees Fahr. This is considerably below the flash point or temperature of inflammability of any reliable motor oil, hence loss or development of abnormal consumption through vaporization can generally be regarded as slight.

Viscosity Defined

Viscosity is regarded as a measure of the relative fluidity of an oil at some definite temperature of observation. In brief it is that inherent property by virtue of which the flow of certain liquids will be retarded. It is possessed by all lubricating oils.

From a technical viewpoint, viscosity can also be regarded as a measure of the resistance which the particles or molecules of an oil will offer to one another as they come into contact in circulation through the lubricating system or between the wearing elements. Viscosity will vary inversely with temperature, i. e., the colder an oil the heavier or more sluggish will it be. In contrast it will become more and more fluid as the temperature is raised.

Reasons for Higher Viscosity Requirements

Modern conditions of higher automotive engine temperatures will lead to an increase in the degree of fluidity of the motor oil which is used for lubrication. Especially will this be true in warm weather, when the amount of external cooling will be appreciably lower than in cold weather.

The utmost care must therefore be taken in the selection of the proper grade of motor oil for warm weather operation in accordance with chart recommendations. Haphazard choice may be the forerunner of too great a reduction in the fluidity of the oil in service, with oftentimes ineffectual lubrication of certain of the wearing parts of the engine as well as abnormal increase in the rate of consumption.

The ultimate occurrence of scored or burned out bearings, of abnormal wear on cylinder walls, and an excess of oil pumping past the piston rings, will all lead to increased cost in car maintenance and a natural decrease in power output.

Oil Gauge Pressure

In this connection oil pressure as shown by the dash gauge must also be considered. The function of this gauge is essentially to indicate that engine lubrication is being maintained. It is not a means of determining the amount of oil delivered to the various working parts, but rather the resistance to pumping involved.

Oil gauge pressure will therefore vary according to the viscosity or relative fluidity of the oil. Oil pressure drop will frequently cause worry to many motorists. It should, however, only be regarded as an indication of impaired lubrication provided pressure is lost entirely, for this may mean a broken or inoperative pump.

With the natural reduction in body or viscosity which is attendant to normal engine operation, resistance to pumping will be proportionately reduced. A certain amount of drop in pressure, especially during intensive or warm weather driving should, therefore, be expected.

In other words, the lighter the oil, the more easily will it pump and circulate, requiring less pressure. Reduction in body or viscosity may be accomplished by heating or dilution. As a result, if oil pressure drops too low it will be an indication that the viscosity of the oil is too low to meet the operating temperatures involved. The reason may be that originally the oil was too light, or that an excess of dilution has occurred.

The remedy is, of course, to use more care in original selection of the oil according to chart recommendations, and to operate with as lean a fuel mixture as possible. Reduced choking, the least amount of idling, and bringing an engine up to operating temperature as soon as possible after starting will all aid largely in this regard.

It will be obvious, therefore, that high or rising gauge pressure should be of far more concern to the motorist, for it may be an indication of faulty lubrication due to a clogged oil line, or the oil being too sluggish and heavy to pump readily and distribute freely to the bearings, or splash to the cylinder walls, according to the type of lubricating system involved.

Definite Information Necessary

In view of the importance of the viscosity characteristic, the motorist should know the approximate range of viscosity involved when he buys a grade of "heavy" motor oil, for example, regardless of who it is manufactured by.

Furthermore, he should know that when an oil is stated as having a viscosity of say 65 seconds Saybolt at 210 degrees Fahr., this means that the body or relative fluidity of the oil in question is such that, at a uniform temperature of 210 degrees Fahr., it will take 60 cubic centimeters of this oil 65 seconds to flow through the orifice of the standard Saybolt viscosimeter.

THE EFFECT OF CARBON RESIDUE

Petroleum products are hydrocarbons; as a result carbon in some chemical form must pass through every automotive engine. It is only a detriment, however, in the form of soot or deposits of carbonaceous tarry matter which may result from evaporation.

Carbon residue may have a very decided effect upon the operation of the engine, the amount of power developed and the amount of "knocking," according to the extent to which deposits are formed on the spark plugs, pistons, cylinder heads, around the rings, on valves and valve seats, and in the crankcase.

Heat and Base of Crude Important

The amount of carbon residue developed will depend entirely upon the degree of heat present, the extent of refinement of the lubricant and the base of the crude from which it is made. From particular types of crude, for example, distillates can be produced which will show an almost negligible carbon residue, 0.05 being a fair idea of the amount to be expected. The use of residual oils, however, for the purpose of blending and increasing the viscosity may easily raise the carbon residue percentage of the resultant product to one per cent or above. Lubricants of this nature will be dark green in color and comparatively opaque.

Carbon which is developed from blended oils containing residual products will, unless specially refined, be harder and more abrasive than carbon residue from lubricants of equal viscosity, but which are wholly of a distilled nature. Hard abrasive carbon does its greatest damage as a promoter of wear on cylinder walls and bearings. Most frequently will it be developed on the upper part of the cylinder walls to be retained by the lubricating film and ultimately worked past the piston rings and into the lubricating system.

All true carbonaceous deposits in the average automotive engine do not, of course, originate from the lubricating oil. Incomplete combustion of the gasoline or an abnormal amount of dilution of the lubricating oil will also tend to increase the amount of carbon formation in the combustion chamber. In other words, the lighter the lubricant or the thinner the film on the cylinder walls, the more readily will it splash or succumb to the wiping effects of the piston. This will, of course, increase the possibility of pumping or forcing of the lubricating film up into the combustion chamber where it will be ultimately burned. The direct result is the development of more or less carbon.

How extensive these deposits may be will, of course, depend upon the residual carbon content of the oil. Where the latter burns cleanly the amount of such deposits will be relatively small. Furthermore, if the oil is properly refined and adapted to the purpose such carbonaceous matter will be soft in appearance, low in quantity and easily removed when cleaning is necessary. Over extended periods of operation, however, carbon deposits, whatever their nature, will be bound to increase.

How Excess Lubricating Oil May Act

Just how an excess of lubricating oil may cause abnormal carbon deposits will be of interest. Theoretically, a very small amount of oil is necessary to maintain the requisite lubricating film on the cylinder walls and serve the respective bearings; actually, however, a considerable excess of oil will be used. Where the rings give the proper degree of seal and the cylinder walls are not abnormally worn, but little of this oil should pass to the combustion chamber. If the oil level is carried too high, however, especially in oiling systems involving splash lubrication, the amount of oil on the cylinder walls may be so excessive that a certain percentage cannot help but find its way into the combustion chamber. A smoky appearance of the exhaust will frequently be an indication of this.

Printed in U. S. A. by
EDGAR C. RUWE CO., INC.
72 Washington St., N. Y. C.